RPV gluinos in Natural SUSY

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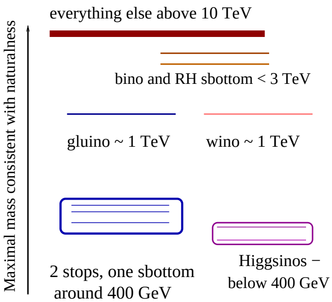
Spectrum of Natural SUSY



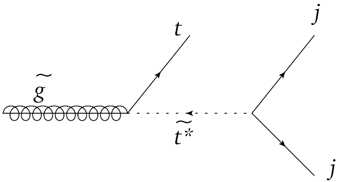
Natural SUSY in nutshell: two light stops, one light sbottom and light Higgsinos. Gluinos cannot be arbitrarily heavy: the should solve the naturalness problem of stops themselves!

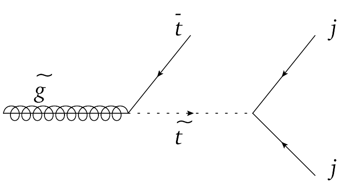
Baryon number violation

This spectrum is already in tension with observations if we assume RP-conserving scenario. However, if baryon number is violated, each stop, if it is an LSP, decays into two "anonymous" jet. This signature is very difficult.

Decay modes of gluinos in natural SUSY

Gluinos have relatively large cross sections and cannot be arbitrarily heavy. Although direct stops production is very difficult in this scenario, we can cover a big portion of parameter space by looking for gluinos.





An event with pair-produced gluinos naively looks like $t\bar{t}$ event with additional jets.

Two types of gluinos

Usually it is assumed that the gluinos are Majorana particles, but it is not the only existing possibility:

Majorana gluinos

$$\Delta m_{\tilde{t}}^2 = \frac{2g_s^2}{3\pi^2} m_{\tilde{g}}^2 \ln \frac{\Lambda}{m_{\tilde{g}}}$$

the correction is divergent, the log is of order ln 100.

expect $m_{\tilde{g}} \lesssim 2m_t$

Dirac gluinos

$$\Delta m_{\tilde{t}}^2 = \frac{2g_s^2}{3\pi^2} m_{\tilde{g}}^2 \ln \frac{\delta}{m_{\tilde{g}}}$$

this correction is finite, δ – SUSY breaking mass of the scalar partner in adjoint chiral s-field. The log can easily be e.g. ln 5, and $m_{\tilde{g}} \lesssim 4m_{\tilde{t}}$.

Predominantly Dirac gluinos also preserve an approximate R-symmetry, so we expect that t and $\bar{t}$ in gluino decays are correlated.

Same-sign dileptons

Gripaios and Allanach, 2012

Big advantage of this approach: very distinctive, low-background signature. Since the backgrounds are small we can safely decrease the cut on $\not{E}_T$, the backgrounds are still under control.

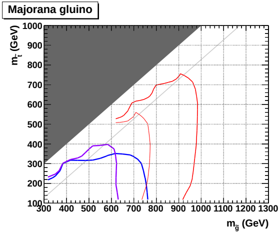
Why would we like to have other tools:

- This is a really powerful tool in RPC case, where we have 4 tops in the event, but in the RPV case there are only 2 tops, BR$\approx 2.5\%$.
- This rate is not model independent. Dirac gluino $\Rightarrow$ approximately conserved R-charge $\Rightarrow$ depleted SS dileptons rate

Can we do better?

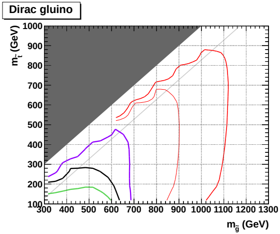
Use more abundant semi-leptonic channel and base cut-and-count techniques on the number of jets and the kinematic of the events!

Constraints on gluinos from existing searches



Blue line - exclusion due to SS dileptonic search (LHC8, $\mathcal{L} = 6\ \mathrm{fb}^{-1}$). Purple line - exclusion due to b' search - monoleptonic search (LHC7, $\mathcal{L} = 1\ \mathrm{fb}^{-1}$).

Black line - BH search (LHC7, $\mathcal{L} = 1\ \mathrm{fb}^{-1}$). Green line - OS dileptons SUSY search (LHC7, $\mathcal{L} = 5\ \mathrm{fb}^{-1}$).



Red lines - estimated reach with our techniques.

Cut-and-count in semileptonic channel

Originally suggested by Lisanti, Shuster, Strassler, Toro, 2011

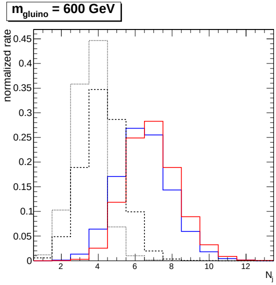
What are the differences between a signal event and $t\bar{t}$ event:

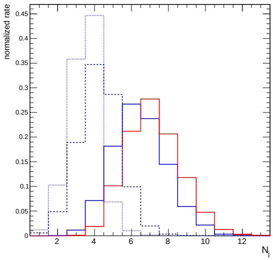
- Expect more jets in average (naively 4 extra-jets)
- Expect much higher H_T

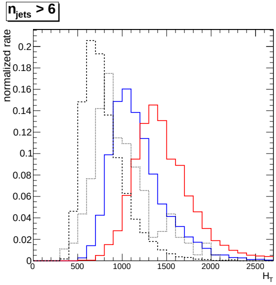
$m_{\tilde{g}} = 600$ GeV, $m_{\tilde{t}} = 100/400$ GeV

$m_{\tilde{g}} = 800$ GeV, $m_{\tilde{t}} = 100/600$ GeV

$m_{\tilde{g}} = 600/800$ GeV, $m_{\tilde{t}} = 140/200$ GeV



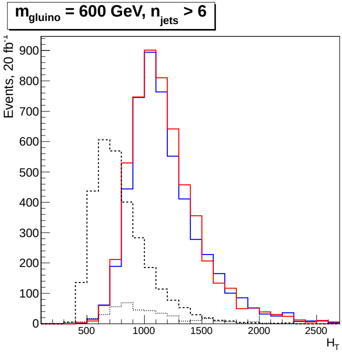




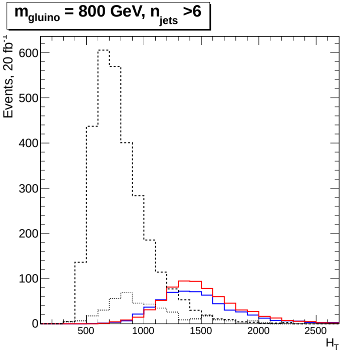
Cut and count experiment

Distribution of H_T in events with 7 or more jets:

Stop masses 100 GeV and 400 GeV:



Stop masses 100 GeV and 600 GeV:



Gluinos up to 800 GeV are accessible with simple cut-and-count techniques, but we should try different cuts windows of H_T.

Reconstruction of resonances: 2 regimes

Cut and counts are promising, but they are also subject to non-negligible systematic uncertainties. Resonance reconstruction should be much cleaner. If $m_{\tilde{g}} \gg m_{\tilde{t}}$ we can easily reconstruct the entire event, because stops and tops in the event are boosted, significantly reducing combinatorial uncertainties. Realistic choice of parameters for the boosted case:

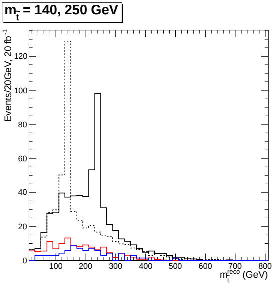
$$\begin{aligned} m_{\tilde{g}} &= 600\ GeV, \quad m_{\tilde{t}} &= 100\ GeV; \\ m_{\tilde{g}} &= 800\ GeV, \quad m_{\tilde{t}} &= 200\ GeV \end{aligned}$$

These mass splittings are big enough to remove combinatorial uncertainties, but still too small to merge jets and leptons $\Rightarrow$ still can apply the cut on more than 6 jets.

If the mass difference is not so big, we cannot use boosted techniques, but there are still two equal-mass jet resonances that we can try to reconstruct.

Reconstruction of boosted events

- Use events which passed cut on H_T, $N \geq 7$ narrow jets and an isolated lepton; recluster with $R = 1.5$, C/A algorithm
- Run top-tagger on the fat jets, if a jet is identified as a top candidate do not consider it for the next step. If more than one candidate have been identified, choose the candidate with the closest mass to 173 GeV. Use top tagger to veto jets, not events.
- Pick up the highest p_T fat jet (which is not top candidate) and decluster it using BDRS procedure. Plot the invariant mass of the subjets inside this jet.

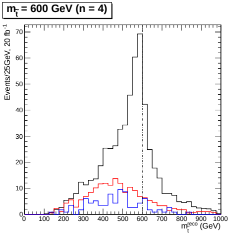


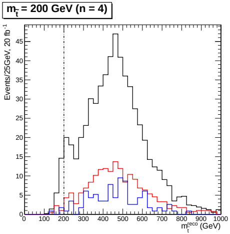
800 GeV Dirac gluino, stop masses - 140 GeV and 250 GeV.

This technique can efficiently reduce any systematic uncertainty which can arise in cut-and-count search.

Not boosted regime

Basic observation. Assume that the stop is much heavier than the top. In this case it is likely that all four leading jets in the event are coming from the stops. We can start from the 4 jets with the highest p_T and reconstruct two same-mass resonances.





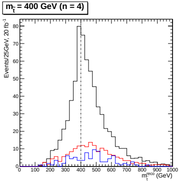
This technique works well for $m_{\tilde{t}} = 600$ GeV. However $m_{\tilde{t}} = 200$ GeV, the peak is completely erased.

Should include lower p_T jet if we are looking for lighter stops.

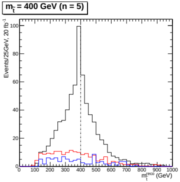
Not boosted regime - modification

Include more jets in the search for the same mass resonances. Try all possible pairing between 5 or 6 leading jets in the even, choose the pair with the minimal invariant mass difference:

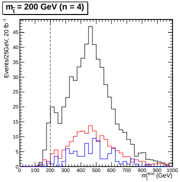
Leading 4j,
$m_{\tilde{t}} = 400$ GeV



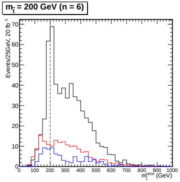
Leading 5j,
$m_{\tilde{t}} = 400$ GeV



Leading 4j,
$m_{\tilde{t}} = 200$ GeV



Leading 6j,
$m_{\tilde{t}} = 200$ GeV



Conclusions

1. If gluinos are below TeV, even cut-and-count experiment in monoleptonic channel should have a good sensitivity for gluinos in RPV scenario. This search should not necessarily have a cut on $\not{E}_T$.
2. Searches in SS-dileptons channel are clean but suffer from low production rates and likely are not ideal.
3. Cut and count combined with peak reconstruction should tell us whether there are gluinos below 1.1 TeV scale even in RPV case.
4. If gluinos are Dirac, naturalness allows gluinos which can be reached only by LHC-14. It is interesting to see how do these searches evolve as we are going to higher energies and we might get real top-jets and stop-jets.
5. It is plausible that a non-negligible portion of $\tilde{g}$ decays into $b, \tilde{b}$. Would be useful to study this RPV "asymmetric" scenario.
6. How does this search behave if the higgsinos are at the bottom of the spectrum? Can we also recosntruct resonances? Should we go just for cut-and-count?